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METHODS OF EVALUATING ULTRA-VIOLET SOLAR RADIATION IN ABSOLUTE UNITS

By W. W. COBLENTZ¹

At the Oxford Meeting (Sept. 12-15, 1936) of the International Commission on Solar Radiation, during the discussion of the use of photoelectric cells in meteorology, the question was raised whether there is not some method of standardizing photoelectric radiometers so that ultra-violet solar radiation intensities can be measured in absolute units, instead of on the arbitrary scale now used. The following is a somewhat elaborated presentation of information given by the writer in his impromptu discussion of this question, at this meeting:

In recent years it has been definitely established that the radiation in the spectral band of ultra-violet, of wave lengths shorter than about 3132Å, in artificial sources and in sunlight, has a specific effect in healing rickets; and by inference it seems to be assumed that these ultra-violet rays have a beneficial effect upon general health conditions.

Whether the latter broad generalization is justified remains to be determined. Nevertheless it is impressive to note how people everywhere, in all walks of life, have come to believe in the beneficent effects of sunlight. Hence, it is the opinion of the writer that meteorological observatories of the various countries would perform a useful service by including measurements of the intensity of the spectral band of ultra-violet radiation of 3132Å and shorter wave lengths in their observations of solar radiation.

The wave length 3132Å is mentioned specifically because it is an intense emission line in the quartz-mercury arc lamp, in common use, which for all practical purposes may be considered the long-wave-length end point in erythral and antirachitic action. (See figure 1 (320m μ = 3200Å).)

METHODS OF EVALUATING ULTRA-VIOLET SOLAR RADIATION

In place of the arbitrary scale, now in use in measuring ultra-violet solar intensities with cadmium photoelectric cells and filters, it is desirable to obtain the measurements in absolute value, independent of the kind of radiometer and filters used.

Recently the writer, in collaboration with R. Stair, (1) (3), has worked out two entirely different methods, which give closely concordant results in evaluating ultra-violet radiation of short wave lengths (shorter than 3132Å in artificial sources and in sunlight) in absolute value for use in medicine (4).

These methods are useful also to meteorologists. Depending upon the judgment of the observer, additional refinements can be made in the calculations, if warranted by the accuracy of the measurements of the ultra-violet intensities, which, owing to great variations in atmospheric transparency, are subject to far greater variations

than the integrated total solar radiation intensities measured even during the clearest weather. The reason that these great variations in ultra-violet intensities are not observed in the measurements of total intensities is because, at the most, the integrated ultra-violet radiation of wave lengths shorter than 3132Å is only about 75 parts in 100,000 of the total solar intensity measured.

The first method designed by us employs a differential thermopile and filters (1). This method requires an accurate knowledge of (a) the ultra-violet spectral transmission of the glass filters, and (b) of the distribution of energy

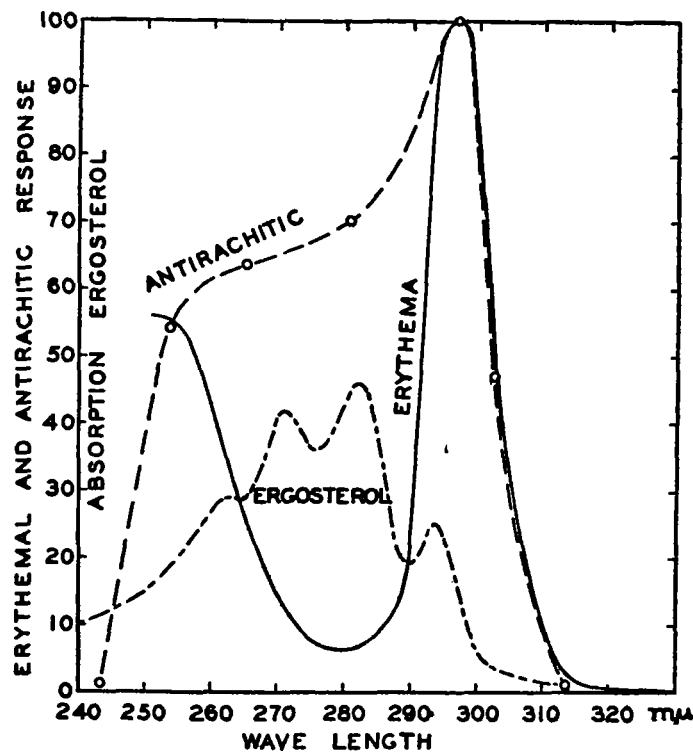


FIGURE 1.

within and adjacent to the spectral band of radiation evaluated. In sunlight this spectral energy distribution, in relative value, is determined by means of a Ti- or Cd-photoelectric cell and suitable filters. The evaluation in absolute units is accomplished by calibrating the combination thermopile-galvanometer radiometer against a standard of thermal radiation (5).

The second method employs a Ti- or Cd-photoelectric cell and glass filters (2). The photoelectric cell is used with a balanced amplifier (Wheatstone bridge) and a microammeter. The novelty in the device is a means of determining the sensitivity of the amplifier at any moment, which is important since the sensitivity varies slightly

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with the temperature, the age of the dry batteries, and the voltage on the filament of the amplifier tube. This method requires a knowledge (a) of the ultra-violet spectral transmission of the filters, (b) of the spectral response of the photoelectric cell and (c) of the distribution of energy within and adjacent to the spectral band of radiation that is to be evaluated. The evaluation in absolute units is obtained by calibrating the photoelectric cell-microammeter radiometer against a standard of ultra-violet radiation, consisting of a special quartz-mercury arc lamp (6).

The second method makes it possible to determine simultaneously, with one instrument, both the *spectral quality* (the spectral energy distribution) and the *total*

tensity measurement is made) it is possible to evaluate the energy in a spectral band, independently of the filter and the photoelectric cell.

Fortunately, photoelectric cells and filters are now obtainable that remain constant. The fact that the spectral response is not the same for all cells of the same type (Ti or Cd) is of no consequence. As a matter of fact, in order to test the applicability of his photoelectric cell and filter method, the writer selected two Ti-photoelectric cells in which the response, in the long wave lengths, terminated in the region of 3300Å and 3500Å, respectively. The main question is the constancy of the photoelectric response over a period of years. The Ti-cells used extensively by the writer have remained constant for over 5 years. But even this question has now been eliminated

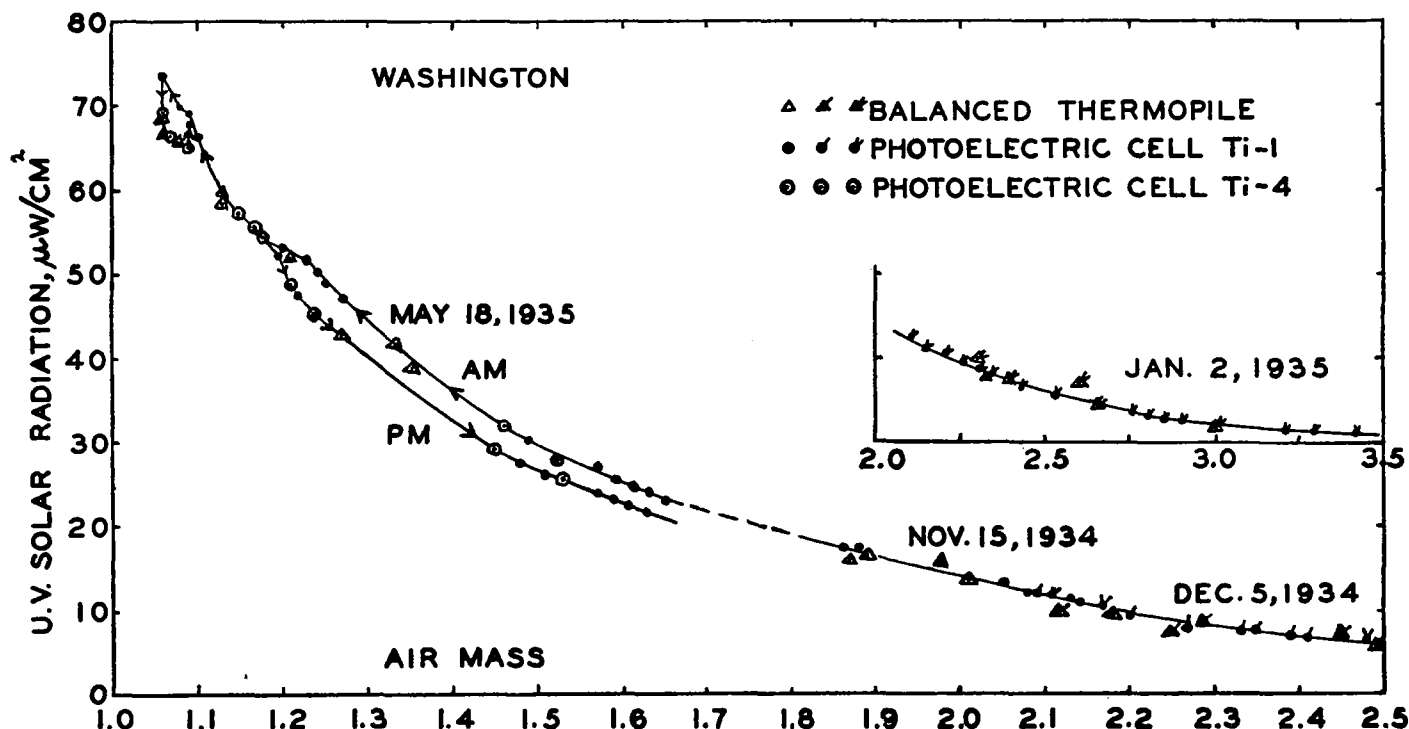


FIGURE 2.

intensity of the ultra-violet radiation of the shortest wave lengths, in sunlight, thus eliminating corrections for change in air mass, etc., during the measurements.

By means of either of these methods a measurement is obtained, in absolute value, of the radiation in the spectral band of wave lengths shorter than about 3132Å, independent of the kind of radiometer.

A typical example of what has been accomplished in evaluating ultra-violet solar radiation in absolute units at different seasons of the year is illustrated in figure 2. The measurements made on May 18, 1935, are interesting because the sky was cloudless throughout the day and only an experienced observer could note a change in turbidity. Nevertheless the photoelectric cell recorded a definite change in transparency of the atmosphere.

It is impractical to employ a large group of filters, having exactly the same spectral transmissions, for use in different observatories. Moreover, it is undesirable to have the measurements in terms of an arbitrary filter and photoelectric cell or thermopile. By knowing (a) the spectral transmission of the filter, (b) the spectral response of the photoelectric cell, and (c) the spectral-energy distribution of the source (which in the case of sunlight is determined at the time the integrated ultra-violet in-

by the use of a standard of ultra-violet radiation (6) for calibrating the apparatus in absolute value.

By cooperating with qualified physicists in their national standardizing institutes, meteorologists of various countries should encounter no difficulties in making these measurements on a uniform (absolute) scale, at least on the clearest days. The worth-whileness of securing a continuous record, during all sorts of weather conditions, remains to be determined.

Since present-day meteorologists are occupied primarily in making measurements of the total solar radiation intensity, in figure 3 is shown the intensity of ultra-violet radiation (u. v. Q), of wave lengths shorter than 3132Å, relative to the total solar radiation intensity (Q) in g cal/cm²/min, on a very clear day in June. As shown in figure 2, at the noon hour, during the clearest days in winter, the ultra-violet intensity in Washington, D. C., is only about one-tenth the value observed under similar conditions at the noon hour in summer.

Detailed descriptions of the experimental procedure and technical details of the calculations involved in the above-described methods of evaluating ultra-violet radiation in absolute units are given in the above-cited papers published in the Journal of Research of the National Bureau

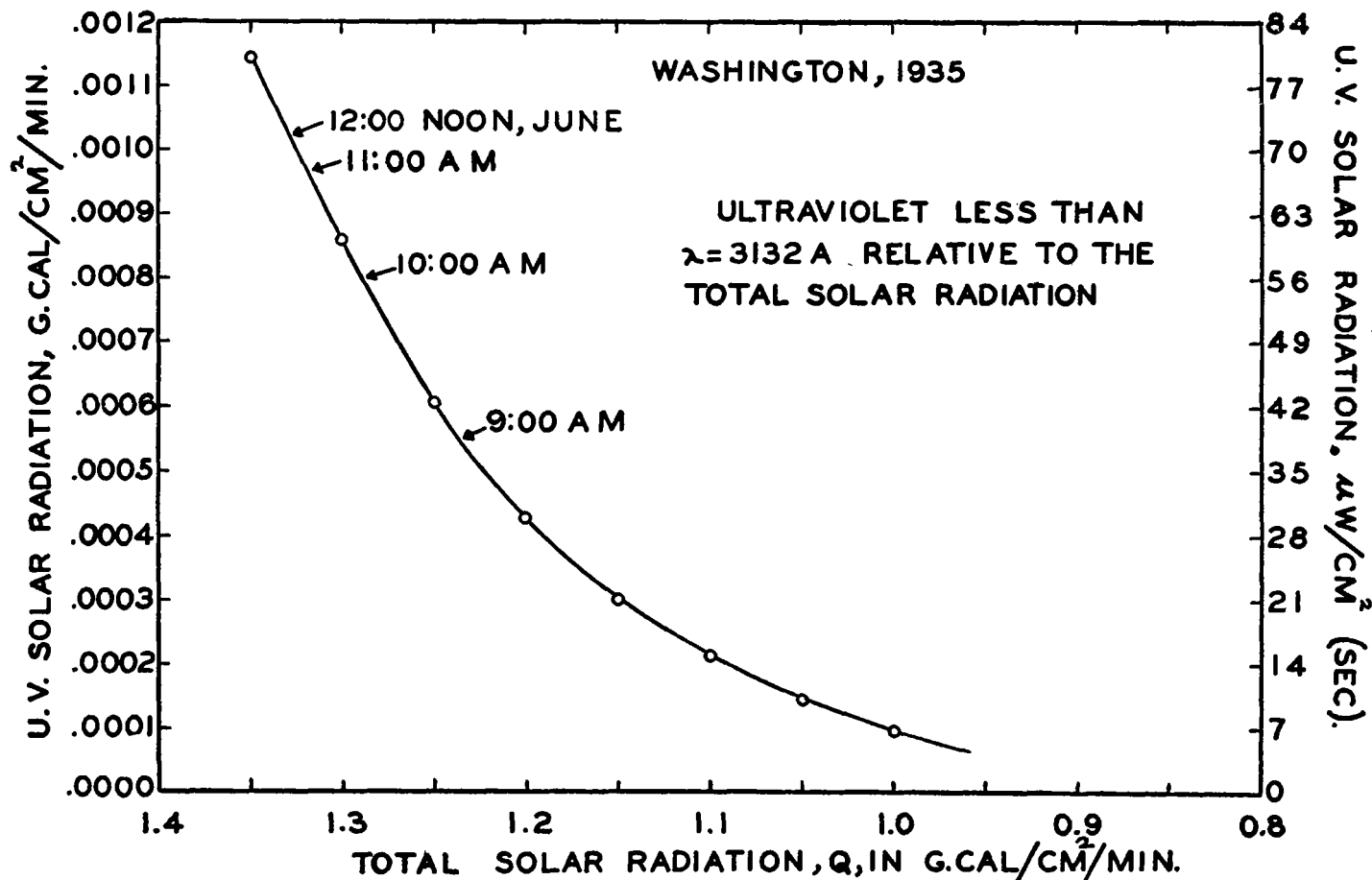


FIGURE 3.

of Standards, Washington, D. C.; and abstracts of this procedure are published in recent issues of *Strahlentherapie* and of the *Annales d'Actinologie*.

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- (3) W. W. Coblenz and R. Stair. *Jr. Res. Nat. Bur. Stds.*, 12, 231, (1934), R. P. 647. A description is given of the construction and performance of a portable ultra-violet meter, consisting of a balanced amplifier (in the form of a Wheatstone bridge) photoelectric cell and microammeter. A novelty in this device is a means of unbalancing the bridge and thereby testing its sensitivity at any moment—an important item apparently overlooked by recent experimenters in this field.
- (4) W. W. Coblenz and R. Stair, *J. Res. N. B. S.*, 16, p. 315 (1936), R. P. 877. The evaluation of ultra-violet solar radiation at sea-level, in the Tropics, and in midlatitude, also measurements at high altitudes, are described. A comparison of the measurements with the differential thermopile and filters (1), (2), and with the photoelectric cell and filter method (3) is described.
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- (6) W. W. Coblenz and R. Stair, *J. Res. N. B. S.*, 16, 83 (1936) R. P. 858. A description is given of a standard source of ultra-violet radiation for calibrating photoelectric dosage intensity meters. In the first-described model a quartz-mercury arc, with one electrode of mercury, was used. In the most recent set-up the source is a newly developed quartz-mercury vapor lamp in which both electrodes are of activated metal and in which there is only a globule of mercury which is completely vaporized. Hence there is no change in density of the mercury vapor with change in temperature.

THE GEOMETRICAL THEORY OF HALOS—I

By EDGAR W. WOOLARD

[Weather Bureau, Washington, D. C., November 1936]

Sundogs or mock suns, and colored rings around the sun or the moon, are more or less familiar to everyone; they have been regarded popularly as indications of the coming weather ever since the time of the Chaldeans. These phenomena may be divided into two general classes, on the basis of their physical origin:

First, when light from the sun or the moon shines through a thin cloud of *water droplets* in the earth's atmos-

phere, the light which passes *between* the droplets is *diffracted*; and, as a result, under appropriate conditions the luminary is observed to be surrounded by one or more series of partial or complete rings, usually small—only a few degrees in radius—and more or less distinctly colored. The colors are arranged in prismatic sequence, *with the red farthest from the source of light*. This optical phenomenon is known to the meteorologist as a *corona*—lunar or solar, as the case may be.